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Work by Prof. Pritchard and his collaborators is summarized here



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# ATOM WAVE INTERFEROMETER

David E. Pritchard

Annual Technical Report for the

Office of Naval Research Contract N00014-89-J-1207
December 1, 1991 - November 30, 1992

Between December 1992 and November 30, 1992, we refined our atom interferometer and started to perform experiments with spatially separated beams. The interferometer is now operating with smaller period gratings, providing greater beam separation. The experiments were performed with the aid of an interaction region that inserts a thin metal foil between the beams. This allowed us to manipulate the atomic wave function in only one arm of the interferometer.

The key component of our interferometer is the set of three matched transmission diffraction gratings which we constructed at the National Nanofabrication Facility (NNF) at Cornell University. The process allows fabrication of precisely positioned openings in thin silicon nitride membranes mounted in silicon frames. The pattern created in the membrane is determined by an electron beam writer, making the process quite versatile. This process was used to create a variety of diffraction gratings used in the interferometer. In addition, several zone plates (atom lenses) were also built, and were later successfully demonstrated.

Our present interferometer consists of three 200 nm period transmission gratings, mounted 0.66m apart on separate translation stages inside the vacuum envelope. During operation, the $0^{th}$ and $1^{st}$ order beams from the first grating strike the middle grating (which is 140 μm wide) where they are diffracted in the $1^{st}$ and $-1^{st}$ orders so that they converge at the third grating. At the second (middle) grating the beams have widths of 30 μm (FWHM) and are separated by 55 μm. The first two gratings form an interference pattern in the plane of the third grating, which acts as a mask to sample this pattern. The detector, located 0.30 m beyond the third grating, records the flux transmitted by the third grating. An interaction region, consisting of a stretched metal foil positioned symmetrically between two side electrodes, is inserted in the interferometer so that the atom wave in the two sides of the interferometer went on opposite sides of the foil. The foil was 10 cm long and 10 microns thick and the gap between the foil and each electrode, where the separated atom beams traveled, was 2mm.

The data necessary to determine the interferometer phase and contrast are acquired by modulating the position of one grating relative to the other two and simultaneously recording the signal from the atom counting electronics as well as the signal from an optical interferometer used to measure the relative position of the gratings. After removing data obscured by noise spikes from the hot wire, the atom count rate data are averaged into bins according to relative grating position, resulting in the fringe pattern. The peak to peak amplitude of our interference signal is 1600 Hz, which enables us to determine the interferometer phase to a precision of 15 m rad in 1 min.

By putting an electric field on one side of the interaction region, the interference pattern is shifted. This phase shift is caused by the DC Stark shift of the atom. The Stark shift is $-\alpha E^2/2$, where $\alpha$ is the electric polarizability and E is the electric field. The measured phase shift was quadratic with the applied field, allowing us to determine the polarizability of the ground state. By observing the reduction of the interference contrast with increasing phase shift, we can measure the longitudinal coherence length of the atomic beam. Our coherence length is 1.6 angstroms, consistent with the measured velocity distribution.

In another experiment, we apply a uniform magnetic field along the beam axis to determine the quantization direction. By running a current down the metal foil, perpendicular to the plane of the interferometer, we increase the field magnitude on one side of the interaction region (thus on one beam) and decrease it on the other. This gives a differential Zeeman energy, and therefore phase, for the two paths that is proportional to the septum current and the projection of the magnetic moment along the beam axis.

The interference pattern of each of the eight sodium ground states shifts independently. There are five different values of the angular momentum projection (one each $m_F \pm 2$, two each $m_F = \pm 1,0$), The different interference patterns superpose to produce an interference pattern whose contrast depends on the differential Zeeman shifts. The first revival of contrast is the point where the phase shifts are: $\pm 4\pi$ for the $|m_F| = 2$ states, $\pm 2\pi$ for the $|m_F| = 1$ states, and 0 for the $m_F = 0$ states.

The scientific future of atoms interferometers looks bright: atom beam sources are inexpensive and intense relative to other particle beams/sources (eg. neutrons, electrons), several techniques have now been demonstrated to make interferometers for them, and the atoms which may be used in them come with a wide range of parameters such as polarizability, mass, and magnetic moment. This assures the applicability of these instruments to a wide range of measurements of both fundamental and practical interest.

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THESIS (undergraduate)

John Berberian, ''Measuring the Isotropic Polarizability of the Sodium Ground State'', S.B. Department of Physics, MIT 1992.

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